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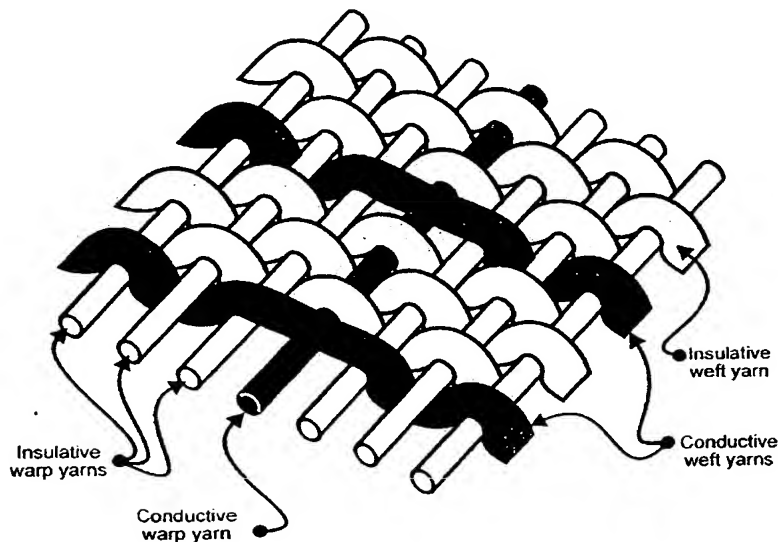
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(54) Title: CONDUCTIVE PRESSURE SENSITIVE TEXTILE



Woven piece of fabric, showing conductive and insulative yarns, with weft floats at crossover points between conductors

(57) Abstract: A fabric including within its construction a first elongated electrical conductor crossed by a second elongated electrical conductor, the conductors being normally biased apart at a crossover point of said fibres with an air gap between them, whereby application of pressure in a direction substantially normal to a plane of the fabric causes the conductors to make contact. The fabric may be woven, knitted, non-woven or plaited. The fabric can be used as a pressure sensor, switch or other sensor.

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## CONDUCTIVE PRESSURE SENSITIVE TEXTILE

The present invention relates to methods of constructing one or more pressure activated electrical switches or sensors in fabric, in the preferred embodiment as integral elements of a single fabric sheet.

- 5 Electrically conductive fabric sheets are known in the art and are described, for example in the applicant's earlier British patent application 2,339,495. The known conductive fabric sheets typically comprise two conductive layers separated by an insulating layer which can be bridged upon application of pressure on the conductive layers. Although such fabric assemblies can function well, there are inevitable drawbacks with having to have three or  
10 more fabric layers, including additional cost, fabric thickness, need to maintain alignment between the various layers, movement of the layers during use and so on.

The present invention seeks to provide an improved conductive textile.

- 15 According to an aspect of the present invention, there is provided a fabric as specified in claim 1:

- The preferred embodiment provides a woven, knitted, non-woven or plaited fabric including in its woven, knitted, non-woven or plaited construction a first elongated  
20 electrical conductor crossed by a second elongated electrical conductor, the conductors being normally biased apart at the crossover point with an air gap between them whereby the application of pressure normal to the plane of the fabric causes the conductors to make contact.

- 25 Preferably, the fabric includes a plurality of spaced first conductors and/or a plurality of spaced second conductors thereby forming a plurality of said crossover points. The conductors may comprise electrically conductive filaments or fibres.

- Advantageously, the fabric is a woven fabric; the warp of which may include at least one  
30 said first electrical conductor and the weft may include at least one said second electrical conductor.

A number of means may be employed, separately or in combination, to bias the conductors apart at the crossover points; in one preferred embodiment this being achieved by including insulating fibres or filaments in the fabric. For example, the biasing apart may be effected by employing, as at least one of the electrical conductors, an electrical  
5 conductor having insulating filament or fibre wound round it to leave the surface of the conductor exposed at the crossover point. In another example, the biasing apart is effected by twisting at least one of the electrical conductors together with insulating filament or fibre. Alternatively, the biasing apart may be effected by employing, as at least one of the electrical conductors, an electrical conductor which is supported on and between  
10 deformable protuberances of an insulating filament or fibre. In another embodiment, the biasing apart may be effected by including in the weave warp and/or weft floats over more than one yarn.

It is preferred that the electrical conductors have an electrical property which is  
15 proportional to or reproducible from the length of the conductor. The length of a conductor or plurality of connecting conductors may then be determined from measurement of that property. Advantageously, the electrical property is resistance.

For some applications, it will be advantageous for the fabric to have at least one set of  
20 spaced electrical conductors, at least some of said set being electrically connected together to form at least one bus bar. Where said set of spaced electrical conductors comprise electrically conductive filaments or fibres in the warp or weft of a woven construction, electrical connection between conductors of that set may be provided by one or more electrically conducting filaments or fibres in the weft or warp, respectively. Alternatively,  
25 said electrical connection may be effected after the weaving process.

In a preferred embodiment, there is provided a fabric including a plurality of weft fibres and a plurality of warp fibres, first and second conductive fibres within the weft and warp fibres and at least one insulating fibre within the weft and/or warp fibres, the insulating  
30 fibre acting to bias apart said first and second conductive fibres so as to provide space therebetween.

The fabric may include a plurality of insulating fibres within one of the weft and warp fibres, which insulating fibres provide a bridge for a conductive fibre in the other of the weft and warp fibres, such that said conductive fibre floats over one or more conductive fibres in the one of the weft and warp fibres.

In another embodiment, one or more insulating fibres is provided around at least one of the conductive fibres, for example helically disposed therearound. Alternatively, one or more conductive fibres could be provided around at least one insulating fibre, with the insulating fibre including portions, for example projections, extending beyond the perimeter of the conductive fibre or fibres. The insulating fibre can thus provide the spacing means for spacing the conductor from other conductors within the fabric layer.

It will be apparent that the invention can provide a conductive textile for a pressure sensor or switch or other conductive device within a single layer of fabric. This can obviate the problems discussed above.

In addition, it is possible to reduce the edge effect (non-linearity of resistance relative to position) which is intrinsic to three-layer structures and which must be corrected for to provide accurate measurements. Moreover, it is possible to have significantly higher resolution, possibly ten times or more, relative to the three layer device; the resolution being dependent upon weaving techniques and fibre dimensions.

With the preferred embodiments, it is possible to provide for contact of the conductive fibres upon the application of a specific pressure or pressures to the fabric and this can be determined by the size of the air gap, the tension of the weave, the deformability of the conductors and the compressibility of the insulators. Moreover, it is possible to provide a range of pressure sensitivities within a single fabric structure. For example, with the embodiment of floating conductor (described with reference to Figure 3 below) different pressure sensitivities can be provided with a plurality of bridges having a different number of conductors below the bridges and/or different insulating fibres, such as different thicknesses or compressibilities. Similar effects can be envisaged with respect to the other embodiments of fibre disclosed herein.

As an alternative, there can be provided two or more layers of the described fabric, having the same or different structures.

- 5 According to another aspect of the present invention, there is provided a fibre including a conductive yarn around which is wrapped at least one insulating yarn. Preferably, there are provided two or more insulating yarns helically wound around the conductive yarn.

10 According to another aspect of the present invention, there is provided a fibre including an insulating yarn around which is wrapped at least one conductive yarn, the insulating yarn including portions extending beyond the conductive yarn or yarns. Preferably, there are provided two or more conductive yarns helically wound around the insulating yarn. The projecting portions could be strands of fibre, protrusions and the like.

- 15 It is possible with the present invention to provide an electrically conductive textile having the features described in British patent application 2,339,495 with only a single layer of fabric.

20 The preferred embodiments of fabric can be significantly cheaper to produce than the structure described in British patent application 2,339,495.

Various embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawings, in which:

- 25 Figure 1 is a perspective view of a grid arrangement of elongate conductors;

Figure 2 depicts the effects of applied pressure on a crossover between two conductors;

Figure 3 is a perspective view of an embodiment of fabric with floating conductors;

30

Figure 4 shows the operation of the fabric of Figure 3;

Figure 5 shows various views of an embodiment of yarn;

Figure 6 shows various views of another embodiment of yarn;

5     Figures 7a to 7c show various embodiments of conductive and insulating yarns;

Figure 8 shows another embodiment of composite yarn;

Figure 9 shows variations of the embodiment of yarn with floating conductors;

10

Figure 10 is a schematic diagram of an embodiment of woven bus bars;

Figure 11 shows an example of technical specification of weave structure; and

15     Figure 12 shows an example of individually addressable multiplexed switches within a woven fabric construction.

Referring to the Figures, in the embodiment of Figure 1, the piece of fabric preferably comprises at least two sets of elongate electrical conductors. Typically, the conductors in  
20     each set are arranged in parallel relative to one another and one set of conductors is arranged perpendicular relative to the other set to form an arbitrarily spaced grid, as shown in Figure 1. The elongated electrical conductors are typically mono-filament or multi-filament conductive fibres, while the remainder of the piece of fabric is composed of insulating fibres.

25

Where any two conductors cross over one another, the construction of the fabric and/or the  
conductive fibres maintains their physical separation, as shown in the cross-sectional view  
of two conductors in Figure 2(a). When pressure is applied normal to the plane of the  
fabric, the conductive fibres are caused to deflect and make electrical contact, as in Figure  
30     2(b). Thus, each crossover point constitutes a momentary contact electrical switch, which will maintain contact while the applied pressure exceeds a threshold. The threshold pressure can be predetermined and controlled at manufacture.

- The switches also exhibit an analogue switching region, as the area of contact shared by the two conductors varies according to the applied pressure, until a maximum contact area is achieved, as shown in Figure 2(c). The manufacturing variables of the piece of fabric can be controlled such that, in use, the switches operate predominantly within this analogue region, demarcated by the dashed lines in Figure 2(d). If this area of contact is measured through some electrical property, for instance resistance, the crossovers can constitute pressure sensors.
- Although the piece of fabric can be of knitted or felted construction, it is envisaged that the primary application of this technology will be to woven fabric structures. In this latter case, the two sets of conductive fibres can constitute warp and weft yarns, respectively, with insulating yarns composing the remainder of the piece of fabric and acting to space apart the individual conductive yarns of each set. A typical example of a woven piece of fabric, incorporating two crossover points, is shown in Figure 3.

#### Separation Techniques

- A number of techniques can be used for maintaining a degree of physical separation between two conductive fibres at a crossover point. These techniques include the use of weave structures with floated yarns and composite conductive/insulating yarns. The different techniques may be used together, allowing, for example, a piece of fabric that incorporates both conductive cored composite yarn and a weave structure with floats.

#### Separation technique - Weaving with floats over one or more yarns

- The first described separation technique is the use of a weave structure with floats, a term applied to a portion of weft yarn that passes over or under more than one warp yarn or vice-versa. To achieve separation of the two conductive yarns at a crossover, typically, the weft conductive yarn is floated over the warp conductive yarn and one or more insulating warp yarns to either side, as is shown in Figure 3. As a result, the two conductive yarns



share little or no physical contact area, as shown in the cross-sectional view, longitudinal to the weft, of Figure 4(a).

If the conductive warp yarn is of smaller diameter than the surrounding insulating warp  
5 yarns, their physical separation can be effected, as shown in Figure 4(b). When pressure is applied normal to the plane of the fabric, the yarns and surrounding fabric deflect, and the two conductors make electrical contact, as in Figure 4(c). Increasing applied pressure increases the area of contact, as in Figure 2(c). The yarns must exhibit sufficient elasticity to recover from the deflection upon removal of the applied pressure, and thus return to  
10 their separated positions, breaking the electrical contact.

Separation technique - Conductive cored yarn encircled with displaceable insulator

Another separation technique involves using a specific composite construction for the  
15 conductive yarns. In this composite yarn, a conductive mono-filament or multi-filament core yarn is twisted, braided, spun, plaited, co-moulded, coated, sleeved or otherwise partially encircled by insulating material, as shown in Figure 5(a).

When a crossover point between two conductive yarns, at least one of which is of this  
20 nature, is not subject to pressure, the insulating material is interposed between the conductors, as in Figure 5(b), ensuring physical separation. However, when subjected to pressure normal to the plane of the fabric, the encircling insulating material can twist, compress, move aside or otherwise deflect to allow electrical contact between the core  
conductor yarns, as Figure 5(c) shows. Upon removal of the applied pressure, the  
25 insulating material springs back into position and/or shape between the conductors to break (open) the electrical contact.

The geometry of the composite yarn and the compressibility, stiffness and surface textures of its constituent yarns contribute to determining the pressure threshold of a crossover  
30 point and can readily be determined by experiment. Composite yarns of this type may be used to construct plain weave crossover points, without the float structures described above.

Separation technique - Compressible, insulating cored yarn encircled with conductor

- Another separation technique involves another type of composite construction for the  
5 conductive yarns. In this composite yarn, which is a reverse case of the yarn detailed  
above, an insulating mono-filament or multi-filament core yarn is twisted, spun, braided,  
plaited, co-extruded, coated, sleeved or otherwise partially encircled by conductive yarns  
or material.
- 10 Additionally or alternatively, a conductive core may be co-extruded with an insulating  
coating and then subjected to post production processing to selectively expose areas of the  
conductive core. The conductive yarns are partially embedded into the insulating core yarn,  
such that the compressible, yielding surface of the core yarn stands proud of the conductive  
yarns, as shown in Figure 6(a). Alternatively, but to the same end, thin conductive yarns  
15 may be twisted or spun with larger insulating yarns such that the insulating yarns stand  
proud of the conductive yarns.

When a crossover point between two conductive yarns, at least one of which is of this  
nature, is not subject to pressure, the insulating material that stands proud of the conductive  
20 yarns ensures physical separation of the conductors, as Figure 6(b). However, when subject  
to pressure normal to the plane of the fabric, the insulating material can compress to allow  
electrical contact between the embedded conductor yarns, as shown in Figure 6(c). Upon  
removal of the applied pressure, the insulating material springs back into position to hold  
the conductors apart and break the electrical contact.

25 The geometry of the composite yarn and the compressibility, stiffness and surface textures  
of its constituent yarns contribute to determining the pressure threshold of a crossover  
point and can be readily determined by experiment. Composite yarns of this type may be  
used to construct plain weave crossover points, without the float structures described  
30 above.

Separation technique – Conductive Cored Yarn Encircled with Displaceable Insulator

Referring to Figures 7(a) to 7(c), there are shown various embodiments of yarn with both insulator and conductor. In Figure 7(a) there is a core yarn substantially circular in cross-section which can be insulating or conductive as desired. Spun, braided or twisted around the core there are larger diameter insulating yarns and smaller diameter conductive yarns. As can be seen in the Figures, when no pressure is applied to the yarn, the conductive fibres remain spaced from the other conductor(s). However, upon application of a compressing force above the threshold, the insulating yarns are compressed and/or moved to allow contact of the conductive yarns on the conductive base (which may be another composite yarn of this type).

In Figure 7(b) there is simply a conductive core having coated thereon or extruded therewith one or more insulating ribs, preferably in a helical arrangement. As can be seen, when no pressure is applied, the conductive core remains spaced from any conductive base upon which the composite is placed (the base may be the another composite structure such as this). However, upon application of a compressive force, there is compression of the insulating rib(s) to allow electrical contact.

In Figure 7(c) a deformable conductive core has formed therewith an insulating sleeve from which sections are then removed to leave grooves with conductive troughs. Compression of the structure will cause deformation of the grooves such that a conductive substrate, which may for example be a plate or fibre-like conductor, will make electrical contact with the conductive core. It is not necessary for any part of the conductive core to be removed to create the groove, merely to enough insulator to be removed to allow access to the core.

Separation technique – Self-Separating Sensory Composite Yarn

In Figure 8 there is shown an embodiment of composite yarn having a core around which there is braided a conductive/insulating yarn with floating conductors, which enables the detection of pressure applied at a point along the length of the structure.

### Parameters Controlling Actuation Pressure

5 A number of controllable manufacturing parameters determine the actuation pressure of a crossover point between two conductors in a woven piece of fabric.

#### a) Relative diameters of conductive and insulating yarns

10 As discussed above, if the conductive yarns in the weave are of a smaller diameter or cross-section than the insulating yarns, the conductive yarns at a crossover point are separated by a greater distance. The conductive yarns must be deflected further in order to make contact, thus requiring a greater actuation pressure.

#### b) Propensity of conductive yarn to make electrical contact

15 A number of variables contribute to the propensity of a conductive yarn to make mechanical electrical contact. Conductive yarns with very smooth and/or hard surfaces tend to smaller areas of contact than fibrous and/or compressible yarns when contacted together under similar pressures. Mono-filament conductors of circular cross-section  
20 similarly offer less contact area than prism shaped or multi-filament yarns. Specifics of the composite yarns are described above.

#### c) Fabric stiffness

25 The actuation pressure required to deflect the conductors at a crossover and make electrical contact is directly governed by the stiffness of the conductive and surrounding insulating yarns, and the general stiffness of the fabric, which in turn is governed by the weave structures used, the yarn spacing and the level of weft compacting, or beat, used. Stiffer fabric requires a greater force for a given deflection and will therefore result in crossovers  
30 of greater actuation pressure.

d) Number of adjacent conductive yarns

If multiple adjacent conductive yarns are used instead of a single warp or weft conductive yarn, as in Figure 9(a), the actuation pressure is reduced. Wider conductors with a greater number of adjacent yarns, as shown in Figure 9(b), both offer a larger contact area at a crossover point and require less angular deflection of the yarns, and thus less pressure, to make contact.

10 e) Number of yarns floated

If a conductive weft yarn is floated over a minimum number of warp yarns to ensure separation at a crossover point, as shown in Figure 9(a), the actuation pressure is correspondingly lesser than if the conductive weft is floated over a larger number of adjacent warp yarns, as shown in Figure 9(c).

Implications to note on actuation pressures

Controlling the aforementioned manufacturing parameters allows crossover points with predetermined actuation pressures to be woven into a piece of fabric: The threshold pressures for both electrical contact to be made and maximal contact to be achieved can be determined independently. Crossover points with different pressure thresholds may be incorporated into a single piece of fabric. This enables the construction of, for instance, a group of neighbouring crossover points that make contact consecutively with increasing pressure and together constitute a quantised pressure sensor.

Another implication of controlling the parameters at a crossover point is that the two conductive yarns may be woven to be in permanent electrical contact, regardless of applied pressure. Principally, this may be achieved through the use of a plain weave structure at the crossover point, where the conductive weft is not floated over any additional warps, but instead shares a large, permanent contact area with the conductive warp yarn. This allows, for instance, the woven construction of bus-bars, discussed herein.

Conversely, if the actuation pressure threshold of a crossover point is made very large, the two conductive yarns may be woven such that they never make electrical contact under typical operating conditions. This allows two conductors to pass over one another and  
5 remain electrically independent. This facility to design crossover points that make or fail to make contact within a grid of conductors allows the routing of current throughout the piece of fabric akin to the tracks of a printed circuit board.

#### Addressing the Matrix of Crossovers

10

Each crossover point between two conductors may be treated as an independent switch, with the array of crossovers constituting a row-column addressed matrix, similar to the majority of existing keyboards. In order to achieve this, each conductive yarn must be individually connected to a suitable circuit for scanning the matrix. Making this number of  
15 connections to the piece of fabric can prove inconvenient.

Alternatively, a scheme which requires far fewer connections to the piece of fabric is to address the matrix of crossovers through electrical bus-bars, as shown in Figure 10. These bus-bars each serve to interconnect the conductors of one set. The number of connections  
20 to the piece of fabric does not scale with the number of crossovers.

The bus-bars may be sewn, embroidered, printed, adhered, mechanically clamped or crimped to the piece of fabric in order to make electrical contact with the matrix of conductors. Most attractively, they can also be of woven construction, integral to the piece  
25 of fabric in a similar manner to the matrix. A typical arrangement is also shown in Figure 10.

Some reproducible electrical characteristic, for example resistivity, can be measured to ascertain the length of a conductor and/or bus-bar. The position of a "closed switch" at a  
30 crossover in the matrix can be deduced from these measurements.

For example, first assume that the conductive yarns of the matrix exhibit a linear resistivity, and that connections are made to three perfectly conductive bus-bars as shown in Figure 10. If the switch at crossover point D is closed, the resistance RAB measured from bus-bar A to bus-bar B is given by:

$$RAB = K ( X + Y )$$

where K is a constant determined by the absolute lengths, cross-sectional areas and resistivities of the conductive yarns, and distances X and Y are the orthogonal vector components of point D, where

$$0 \leq ( X, Y ) \leq 1.$$

Similarly, the resistance measured from bus-bar B to bus-bar C is given by:

$$RBC = K ( Y + 1 - X ).$$

Substituting gives:

$$X = [ ( ( RAB ) / K ) - ( ( RBC ) / K ) + 1 ] / 2$$

and:

$$Y = [ ( ( RAB ) / K ) + ( ( RBC ) / K ) - 1 ] / 2.$$

#### A typical example

This section details an example of weaving instructions for constructing a typical piece of fabric. A piece of fabric of arbitrary size may be reproduced from these specifications, although the repeat for a 250 mm width has been included. The crossover points are evenly spaced in a grid some 8.5 mm apart. Using the specified yarns and weave structures, the pressure threshold of the crossover points is roughly 80 kiloPascals, equivalent to 4

Newton force on a typical fingertip area of 50 square millimetres. The specifications also incorporate two bus-bars in the warp yarns, at either side of the piece of fabric.

5 The warp has been designed with two selvedge edges consisting of a twisted multi-filament yarn, BASF F901 G004, 8 warp threads at either edge of the warp on shafts 1-4, shown diagrammatically in Figure 10(a).

10 The warp continues to use a 100% cotton 2/18's yarn set at 24 ends per inch. This is interspersed with conductive mono-filament type BASF F901 A013 every 8 warp threads on shafts 8, 16 and 24.

The lifting sequence/ peg plan determines the order in which the shafts are moved to lift or leave the warp threads.

15 A weft thread of the same cotton is passed through the shed of lifted warp threads, as in the peg plan of Figure 10(b) and substituted with the conductive mono-filament F901 A013 on every 6th pick. This determines the weft thread floats over the conductive warp threads.

## 20 Individually Addressable Multiplexed Switches Within a Woven Fabric Construction

Figure 12 shows an embodiment of individually addressable multiplexed switches which can be formed from any of the embodiments described above. As can be seen, a grid of conductor crossover points are produced, by any of the above-described methods, and two  
25 bus bars provided with the permanent electrical connections as shown in the Figure. The switches provide, when closed, the closed circuits as shown in the example matrix configurations. More specifically, when each input line D\* is connected to a positive potential in turn, the three resulting 3-bit patterns produced at the outputs Q1, Q2, Q3 uniquely identify a closed switch within the matrix of crossovers. Connecting the matrix  
30 to the inputs D1, D2 and D3 and outputs Q1, Q2 and Q3 according to a binary code allows more graceful response to multiple closed switches therein.



CLAIMS

1. A fabric including within its construction a first elongated electrical conductor crossed by a second elongated electrical conductor, said conductors being normally biased  
5 apart at a crossover point of said fibres with an air gap between them, whereby application of pressure in a direction substantially normal to a plane of the fabric causes the conductors to make contact.
2. A fabric according to claim 1, including a plurality of spaced first conductors  
10 and/or a plurality of spaced second conductors, forming a plurality of said crossover points.
3. A fabric according to claim 1 or 2, wherein the conductors comprise electrically  
15 conductive filaments or fibres.
4. A fabric according to any one of claims 1 to 3, which is woven, knitted, non-woven  
or plaited.
5. A fabric according to claim 4, including warp and weft filaments, wherein the warp  
20 filaments include said first electrical conductor or conductors and the weft filaments include said second electrical conductor or conductors.
6. A fabric according to any preceding claim, including insulating fibres or filaments  
25 which bias the first and second electrical conductors apart at the crossover point.
7. A fabric according to claim 6, wherein said biasing apart is effected by locating an  
electrical conductor of relatively smaller cross-section between insulating filaments or  
fibres of relatively larger cross-section.
8. A fabric according to claim 6, wherein the weave includes warp and/or weft floats  
30 over more than one yarn to effect the biasing apart of first and second electrical conductors at the crossover point.

9. A fabric according to claim 6, wherein said biasing apart is effected by employing, as at least one of the electrical conductors, an electrical conductor including insulating filament or fibre wound around it to leave the surface of the conductor exposed at the crossover point.

10. A fabric according to claim 6, wherein said biasing apart is effected by twisting at least one of the electrical conductors together with insulating filament or fibre.

11. A fabric according to claim 6, wherein said biasing apart is effected by employing, as at least one of the electrical conductors, an electrical conductor which is supported on and between deformable protuberances of an insulating filament or fibre.

12. A fabric according to any preceding claim, wherein the electrical conductors have an electrical property which is proportional to the length of the conductor, whereby the length of a conductor or plurality of connecting conductors can be determined from measurement of that property.

13. A fabric according to claim 12, wherein the electrical property is electrical resistance.

14. A fabric according to any preceding claim, including at least one set of spaced electrical conductors, at least some of said set being electrically connected together to form at least one bus bar.

15. A fabric according to claim 14, wherein said set of spaced electrical conductors comprises electrically conductive filaments or fibres in the warp or weft of a woven construction and electrical connection between conductors of that set is provided by one or more electrically conducting filaments or fibres in the weft or warp, respectively.

16. A fabric according to claim 14, wherein set of spaced electrical conductors comprises electrically conductive filaments or fibres in the warp or weft of a woven construction and said electrical connection is effected after the weaving process.

- 5 17. A fibre including an insulating yarn and a conductive yarn, the insulating yarn including portions extending beyond the conductive yarn.

18. A fibre according to claim 17, wherein there are provided two or more conductive yarns helically wound around the insulating yarn.

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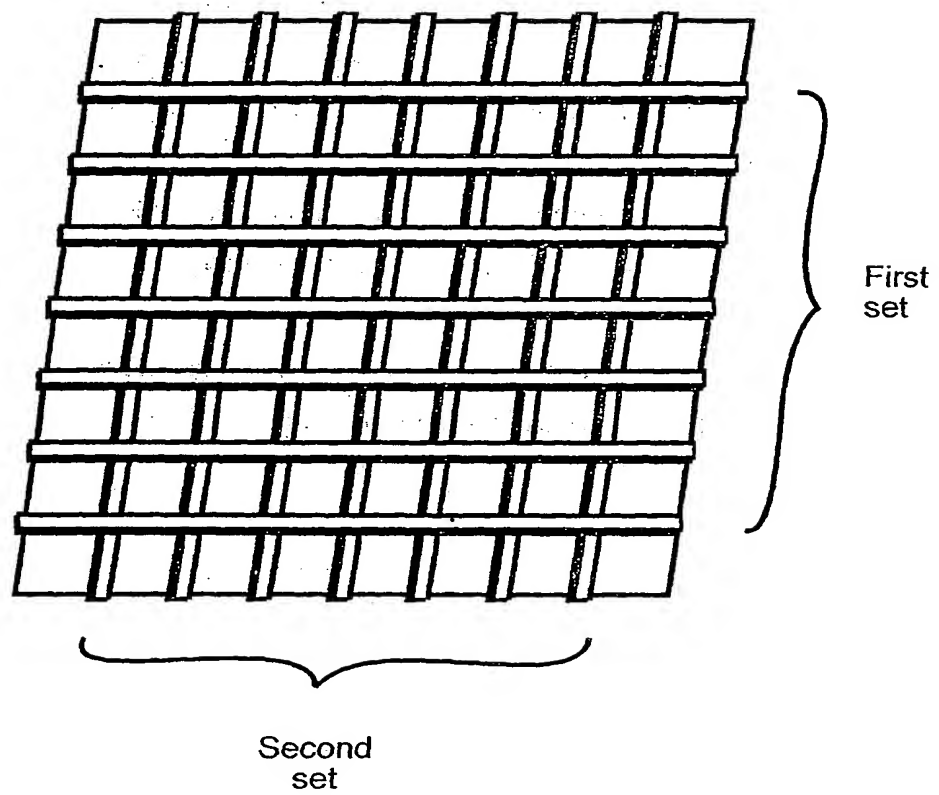
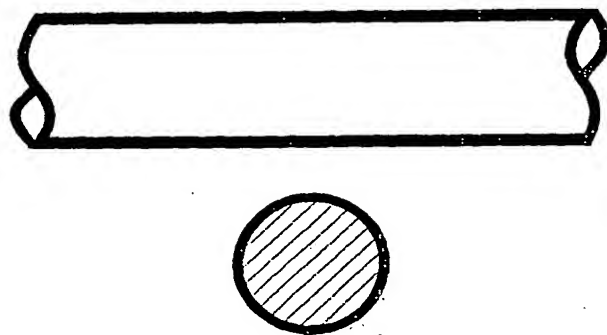
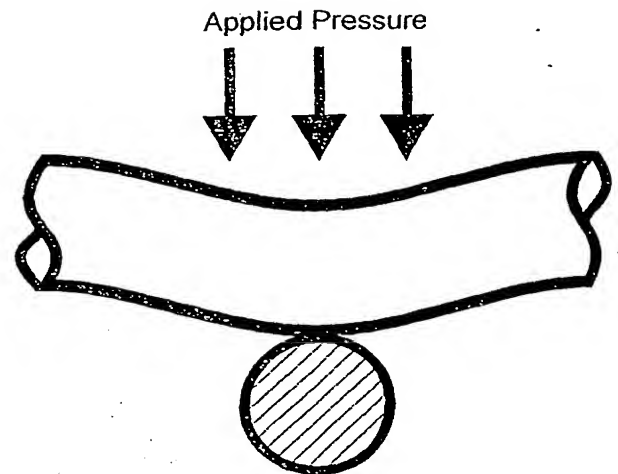


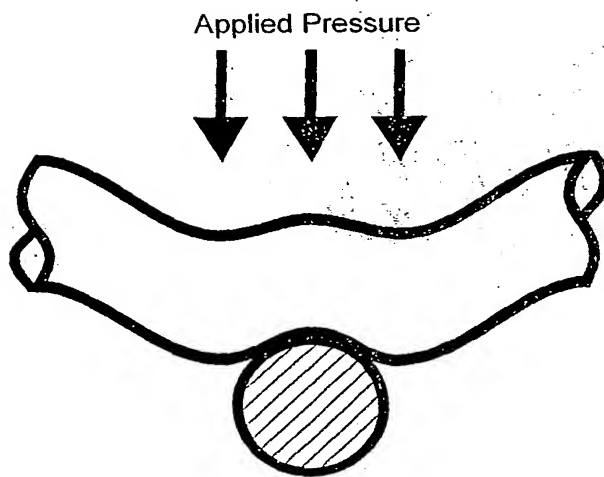
Figure 1. Grid arrangement of elongated conductors



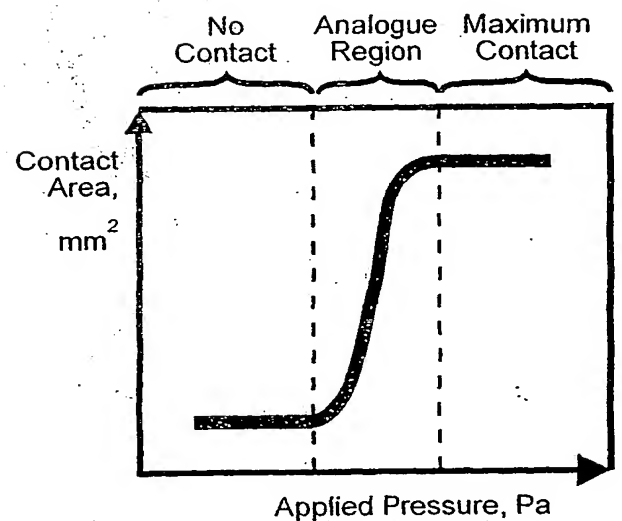
a) No contact area  
between conductors



b) Little contact area  
between conductors



c) Maximum contact area  
between conductors



d) Graph of applied pressure on a  
crossover versus area of contact  
between the conductors,  
showing analogue switching region

Figure 2. Effects of applied pressure on a crossover between two conductors, cross sectional views and plotted relationship

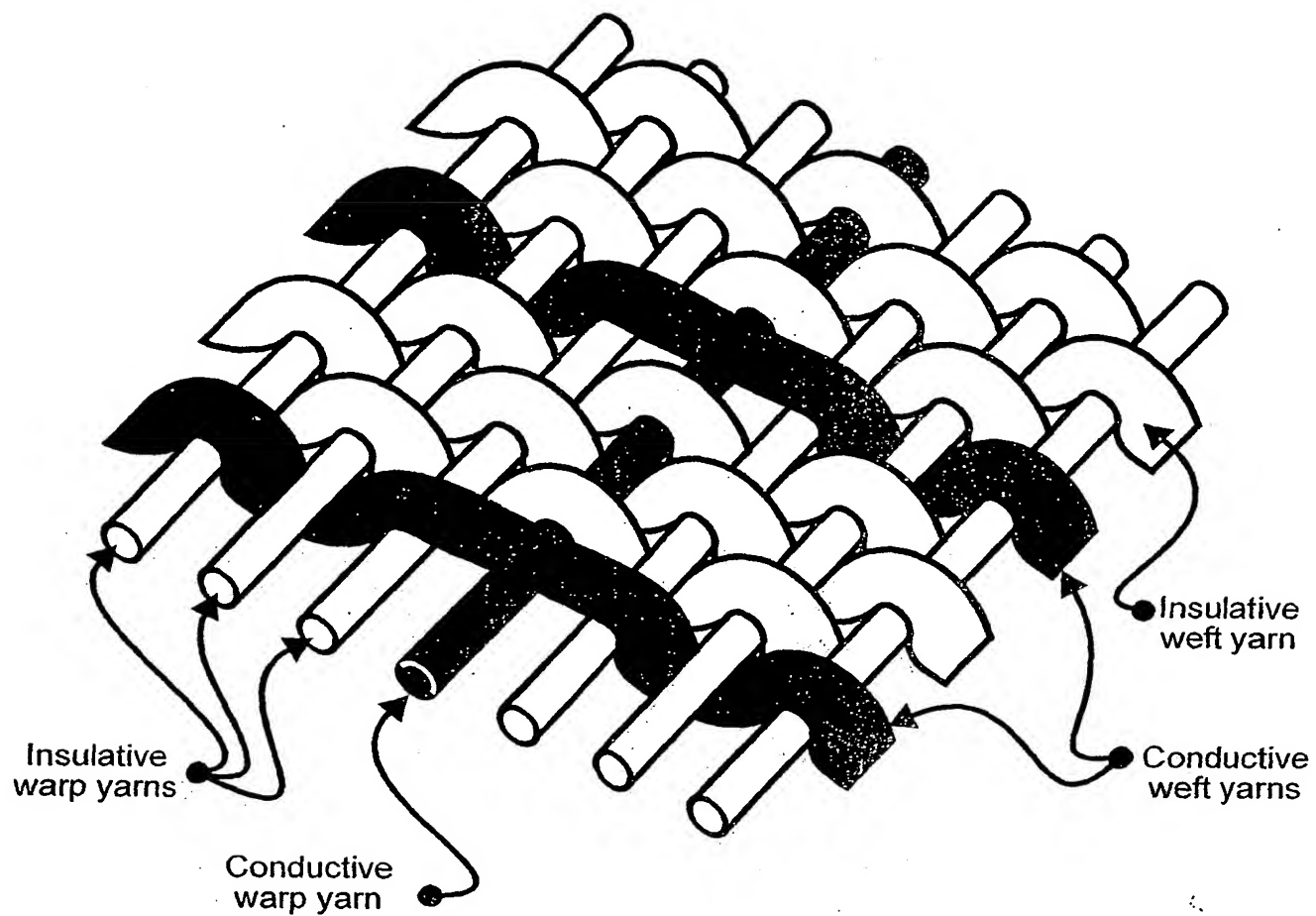
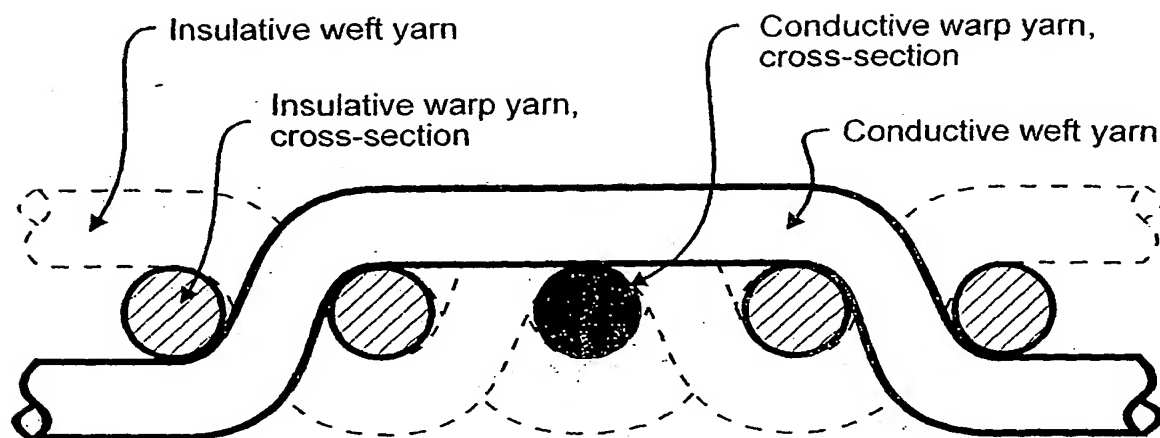
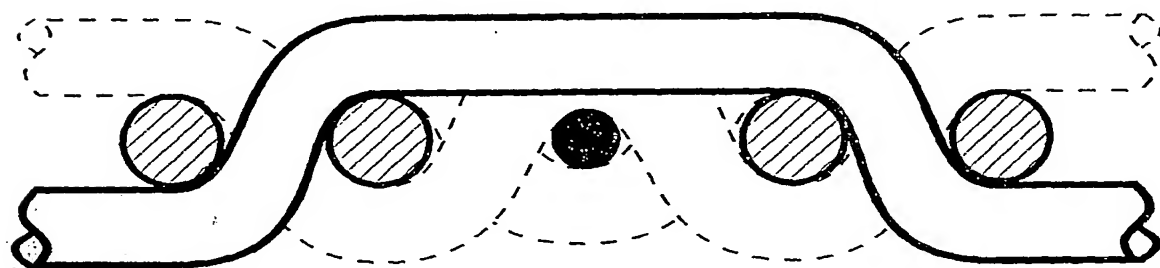


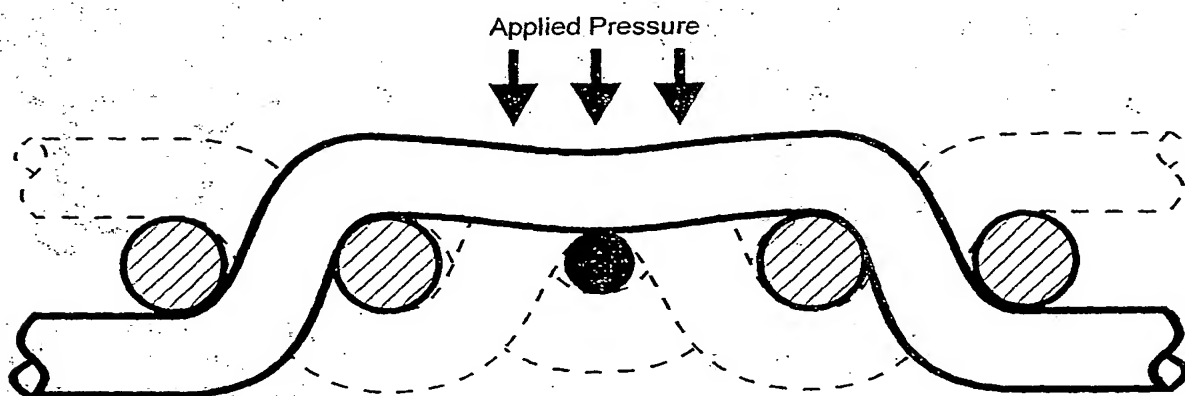
Figure 3. Woven piece of fabric, showing conductive and insulative yarns, with weft floats at crossover points between conductors



a) Conductive weft floated over conductive warp results in minimal contact area

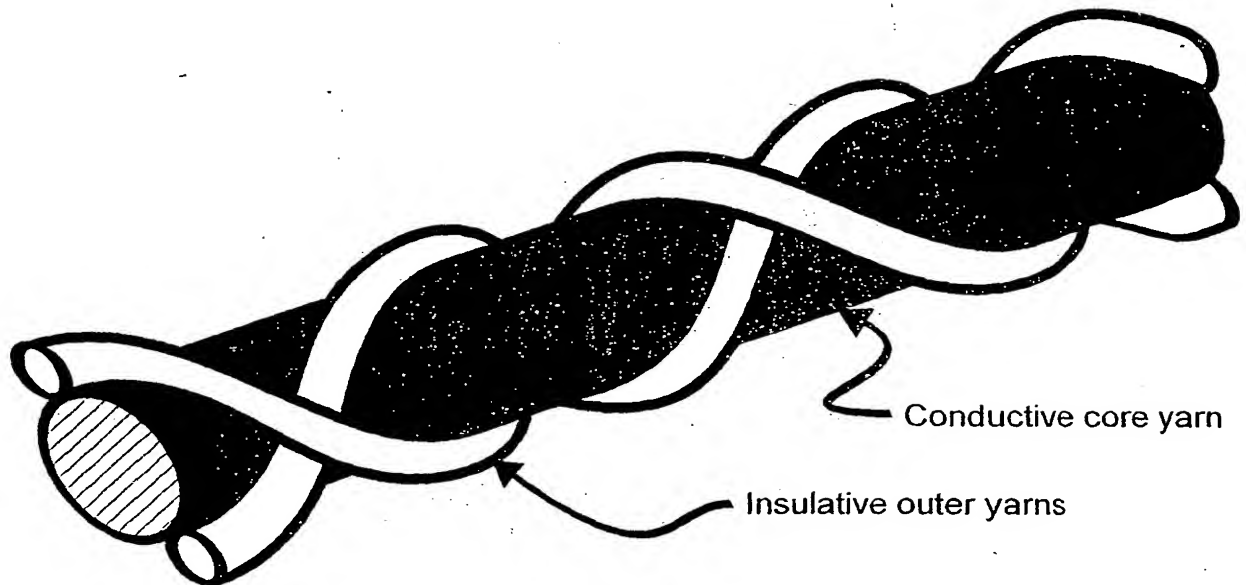


b) As (a) but smaller diameter conductive warp results in physical separation

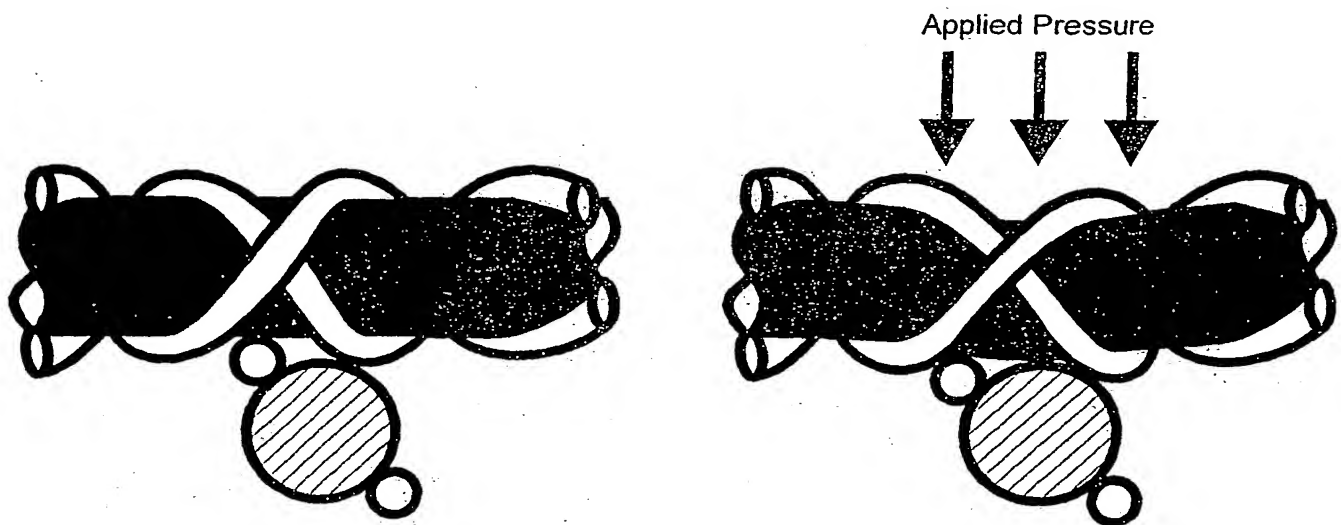


c) Pressure applied to structure (b) effects contact between the conductors

Figure 4. Weaving conductive yarns with weft floats at crossovers to control contact area, cross sectional views



a) Conductive cored yarn with partially encircling insulation, perspective view

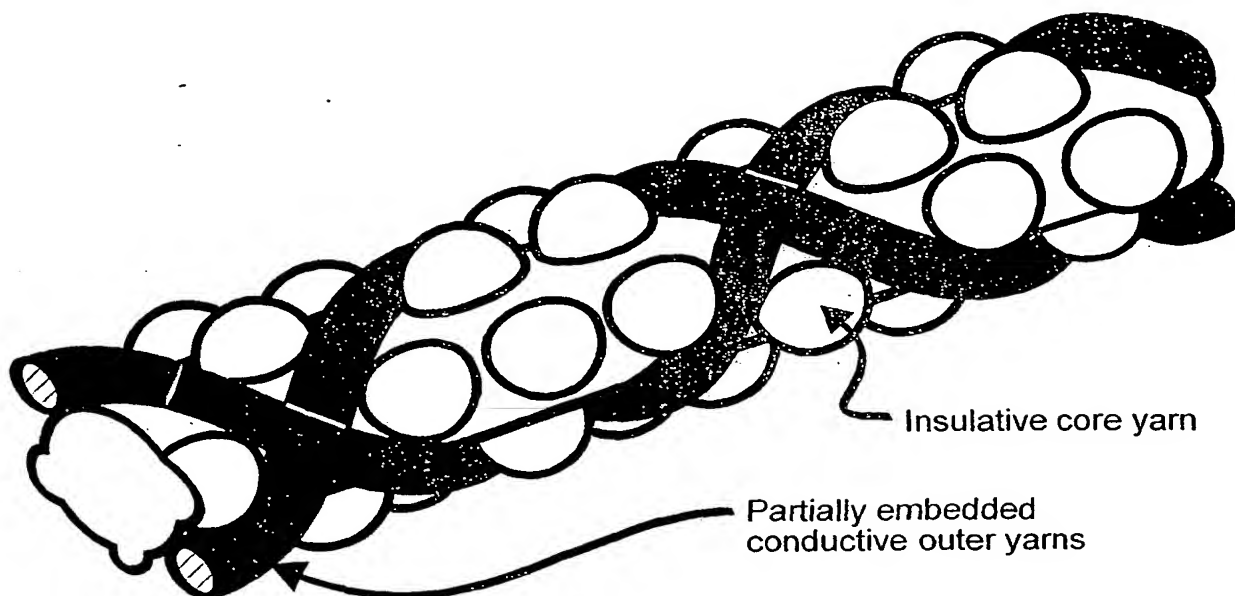


b) Insulative yarns hold conductive yarns apart

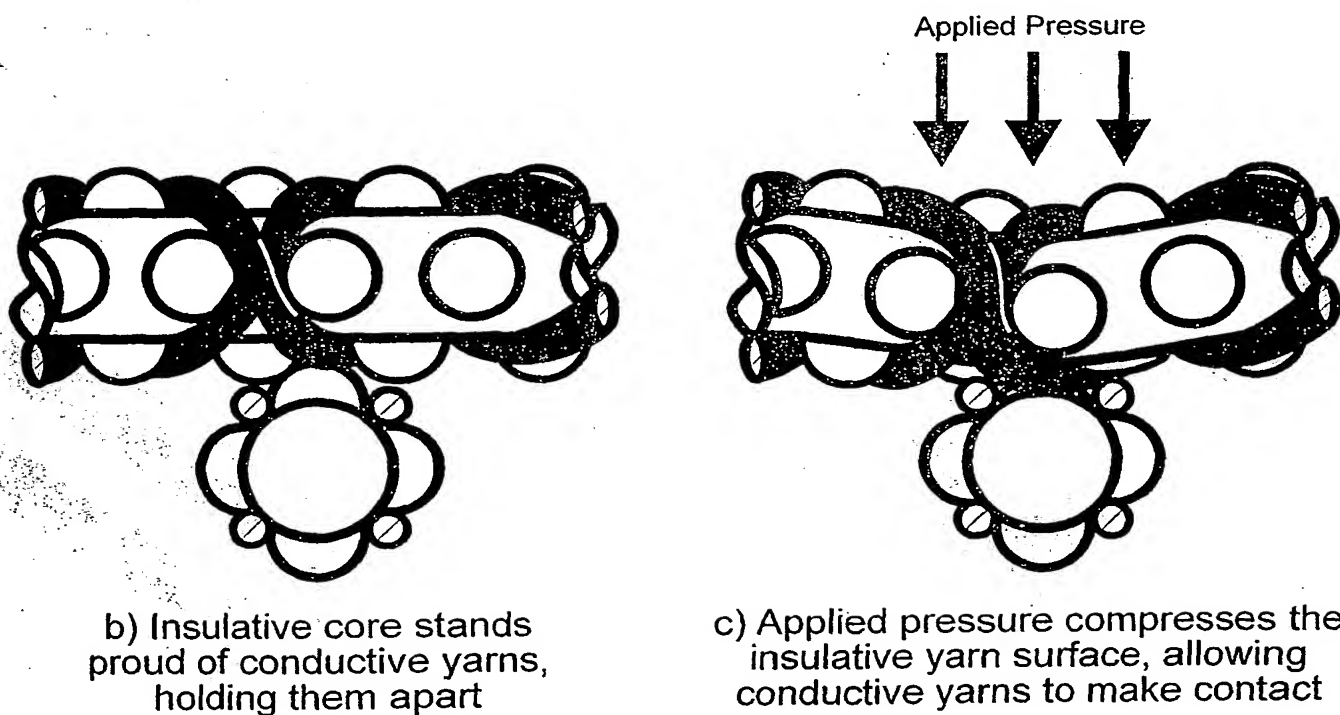
c) Applied pressure deflects insulative yarns, allowing conductive yarns to make contact

Figure 5. Conductive cored yarn with partially encircling insulative yarns as a separation technique





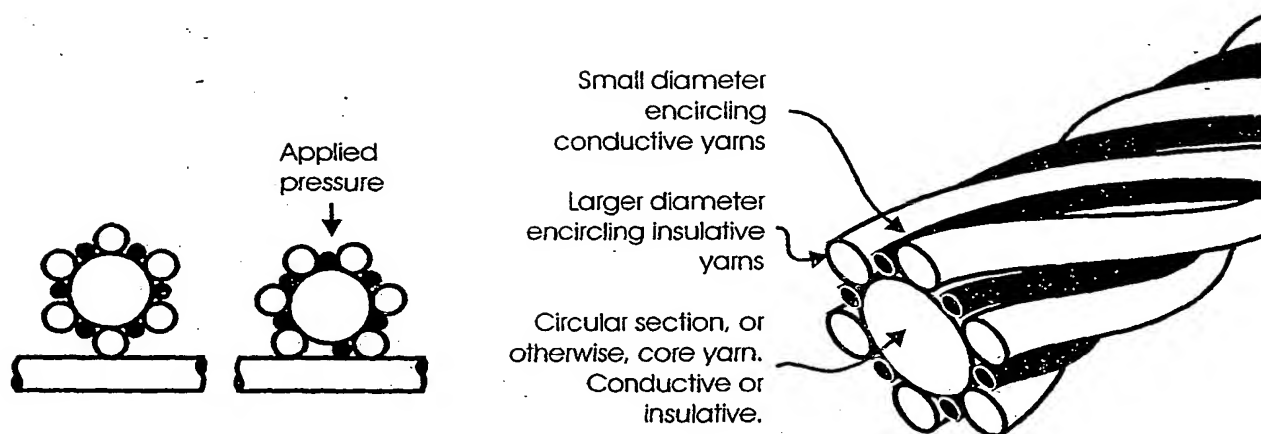
a) Conductive encircling yarn partially embedded into insulative core yarn, perspective view



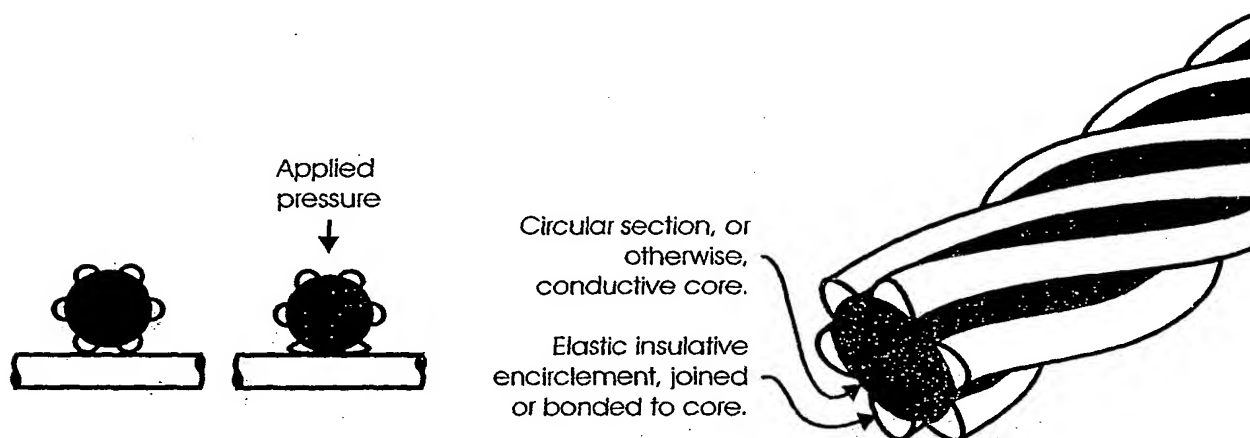
b) Insulative core stands proud of conductive yarns, holding them apart

c) Applied pressure compresses the insulative yarn surface, allowing conductive yarns to make contact

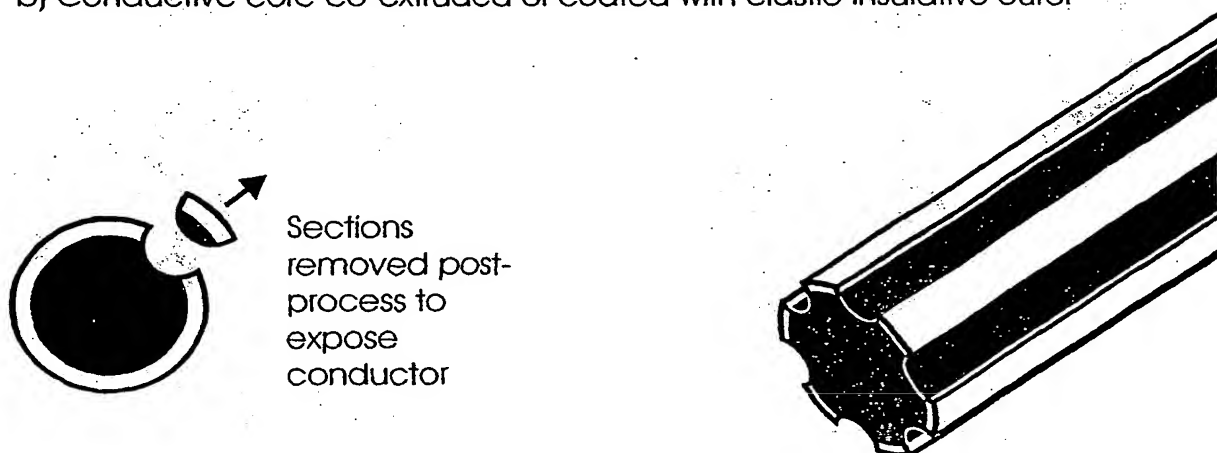
Figure 6. Insulative cored yarn with embedded conductive yarns as a separation technique



a) Small diameter conductive yarns spun, braided or twisted with larger diameter insulative yarns.



b) Conductive core co-extruded or coated with elastic insulative outer



c) As (b) but co-extruded or coated and then partially stripped of insulative outer layer

Figure 7. Conductive cored yarn encircled with displaceable insulator as a separation technique

The yarn may be used as-is, or woven into fabric, or applied to a substrate post-manufacture, e.g. embroidered to a fabric.

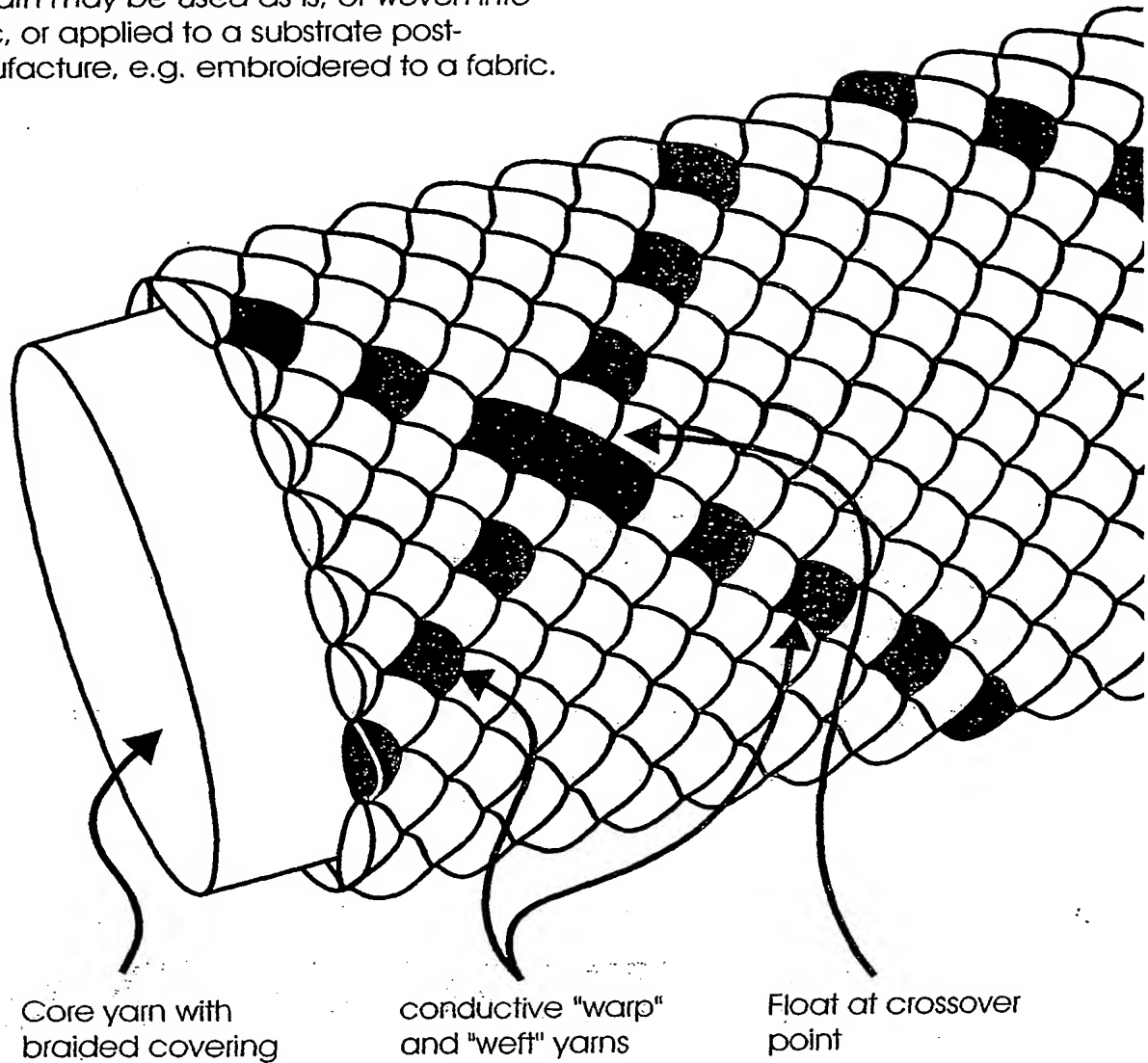
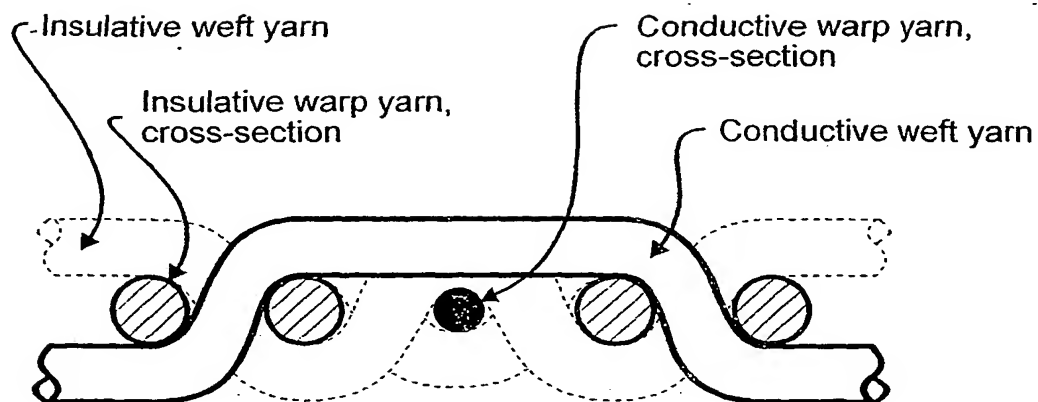
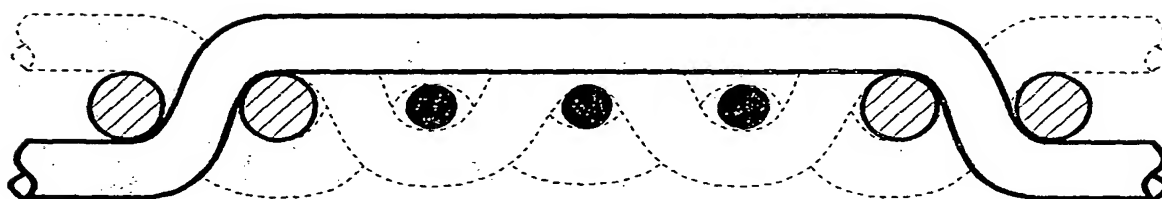


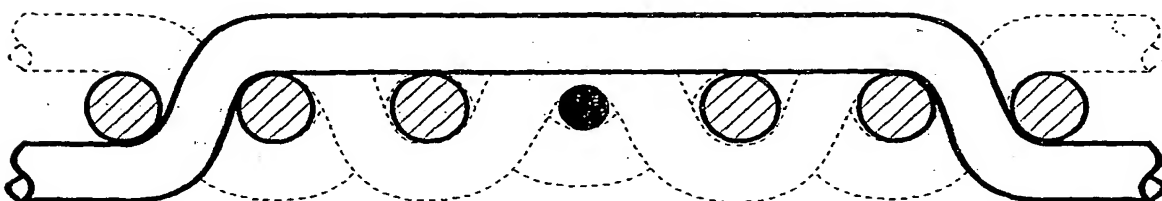
Figure 8. Translation of the described techniques from a weaving to a braiding process. The resulting composite yarn can detect an applied pressure at some point along its length



a) Basic configuration



b) Greater number of conductive warp yarns at a crossover



c) Greater number of floated insulative warp yarns at a crossover

Figure 9. Variations of floated weave structure, cross sectional views

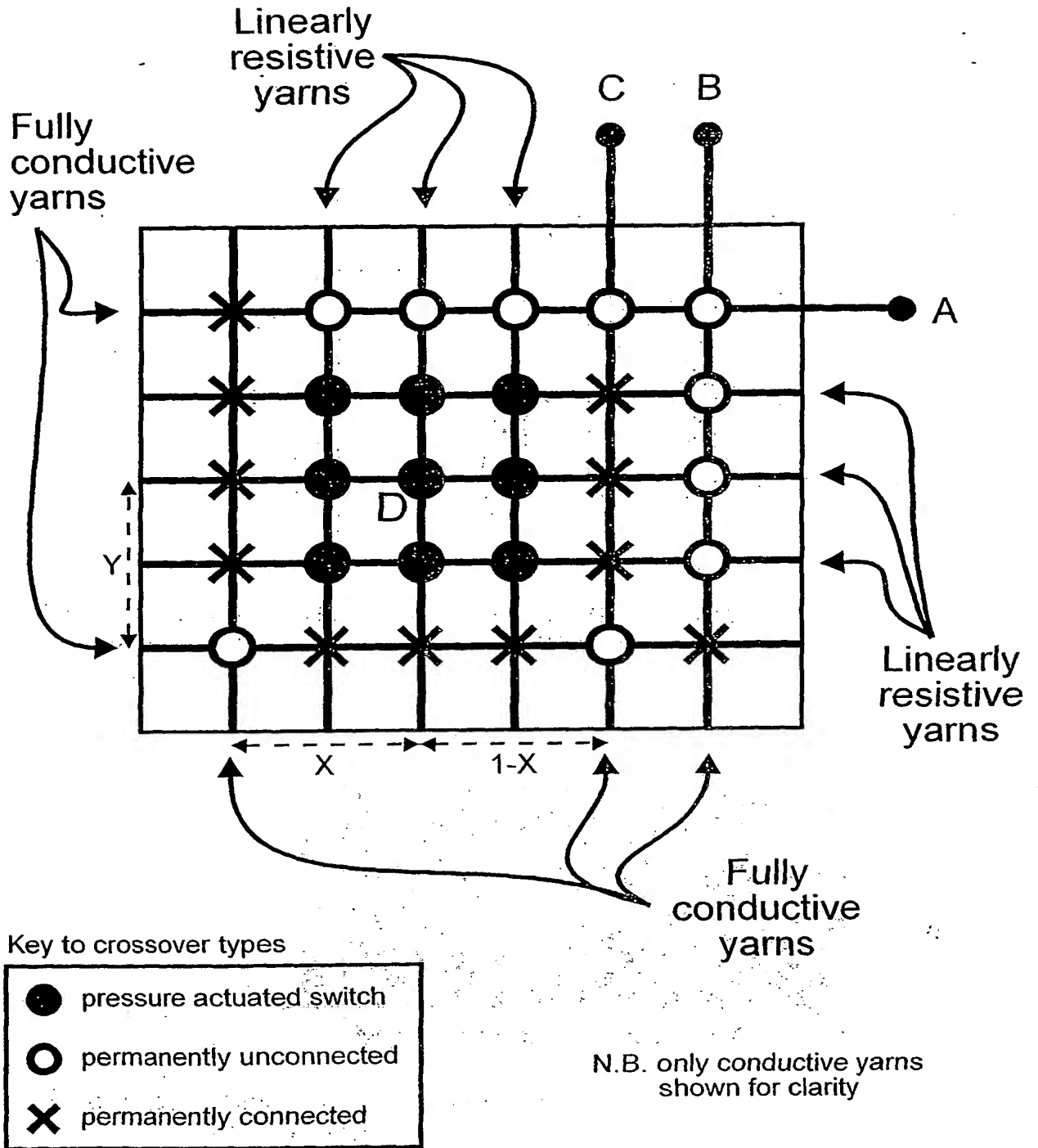
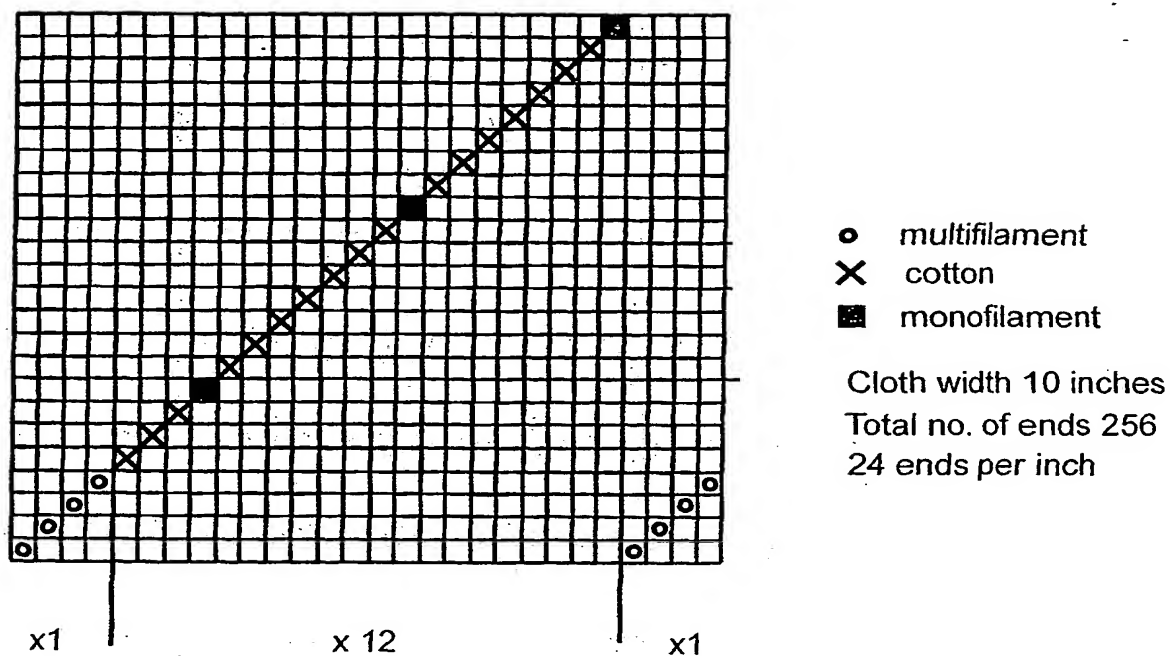
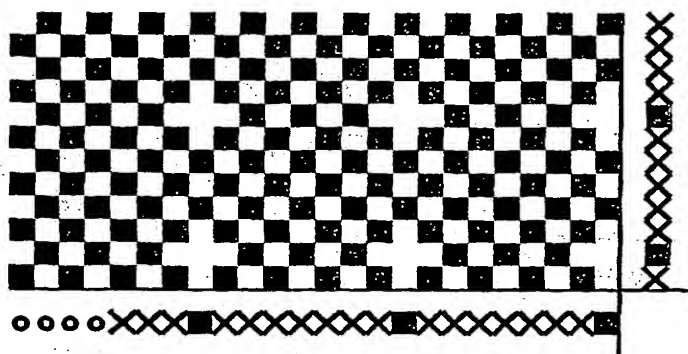


Figure 10. Woven bus-bars: arrangement and weave structure



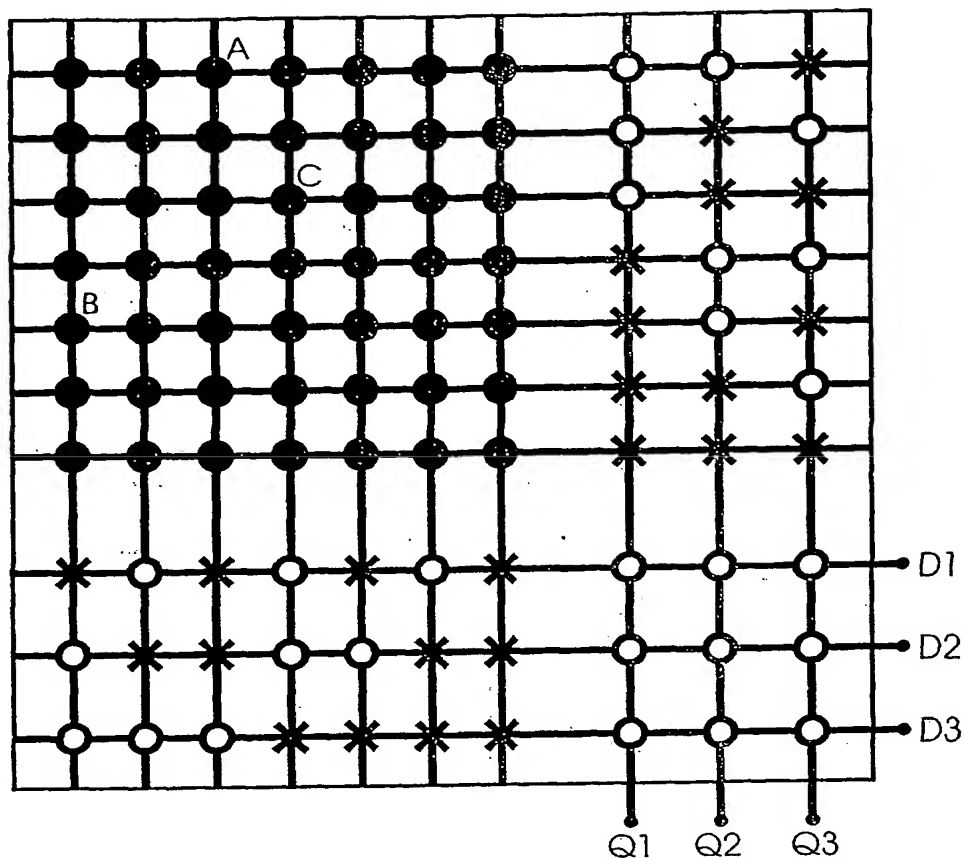
a) Warp design over 24 shafts using conductive multifilament, cotton and conductive monofilament.



b) Lifting sequence/ Peg plan using cotton and conductive monofilament

Figure 11. Technical specifications for weave structure.

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Examples of matrix interrogations

Switch	D1	D2	D3	Q1	Q2	Q3
PointA	1	0	0	0	0	1
	0	1	0	0	0	1
	0	0	1	0	0	0
PointB	1	0	0	1	0	1
	0	1	0	0	0	0
	0	0	1	0	0	0
PointC	1	0	0	0	0	0
	0	1	0	1	0	0
	0	0	1	0	1	1

N.B. only conductive yarns shown for clarity

Key to crossover types

- pressure actuated switch
- permanently unconnected
- ✕ permanently connected

Figure 12. Individually addressable multiplexed switches within a woven fabric construction

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 01/01518

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G06K11/12 G06K11/10 D02G3/12 G01L1/20

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G06K D02G G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 989 509 A (ELECTROTEXTILES COMP LTD) 29 March 2000 (2000-03-29) paragraphs '0040!-'0044!; figures 4,5	1-6,12, 13
A	US 4 795 998 A (DUNBAR JOHN H ET AL) 3 January 1989 (1989-01-03) column 8, line 13 -column 9, line 20; figures 1A,5,6	1
X	EP 0 911 435 A (BEKAERT SA NV) 28 April 1999 (1999-04-28) claim 1	17,18
X	EP 0 222 239 A (FORSCH ENTWICKLUNG VEB) 20 May 1987 (1987-05-20) claim 1	17,18

☐ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	--- Publication date
EP 0989509 A	29-03-2000	GB 2341929 A	29-03-2000
		GB 2341930 A	29-03-2000
		GB 2341931 A	29-03-2000
		AU 4877099 A	30-03-2000
		EP 1100044 A	16-05-2001
		JP 2000112640 A	21-04-2000
		GB 2341932 A,B	29-03-2000
		GB 2341978 A,B	29-03-2000
		GB 2341933 A,B	29-03-2000
US 4795998 A	03-01-1989	AT 51447 T	15-04-1990
		CA 1260729 A	26-09-1989
		DE 3576850 D	03-05-1990
		EP 0161895 A	21-11-1985
		JP 61010734 A	18-01-1986
EP 0911435 A	28-04-1999	US 5927060 A	27-07-1999
EP 0222239 A	20-05-1987	DD 251472 A	18-11-1987
		DD 259537 A	31-08-1988
		BG 51910 A	15-11-1993
		CS 8607144 A	12-11-1987
		DE 3675152 D	29-11-1990
		HU 57840 A	30-12-1991
		JP 62162037 A	17-07-1987
		SU 1691437 A	15-11-1991
		US 4840202 A	20-06-1989
		JP 62289632 A	16-12-1987
		CS 8701086 A	12-09-1989
		JP 63211343 A	02-09-1988

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